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Predictability of the Power Output of Three Wave Energy Conversion Technologies in the Danish Part of the North Sea

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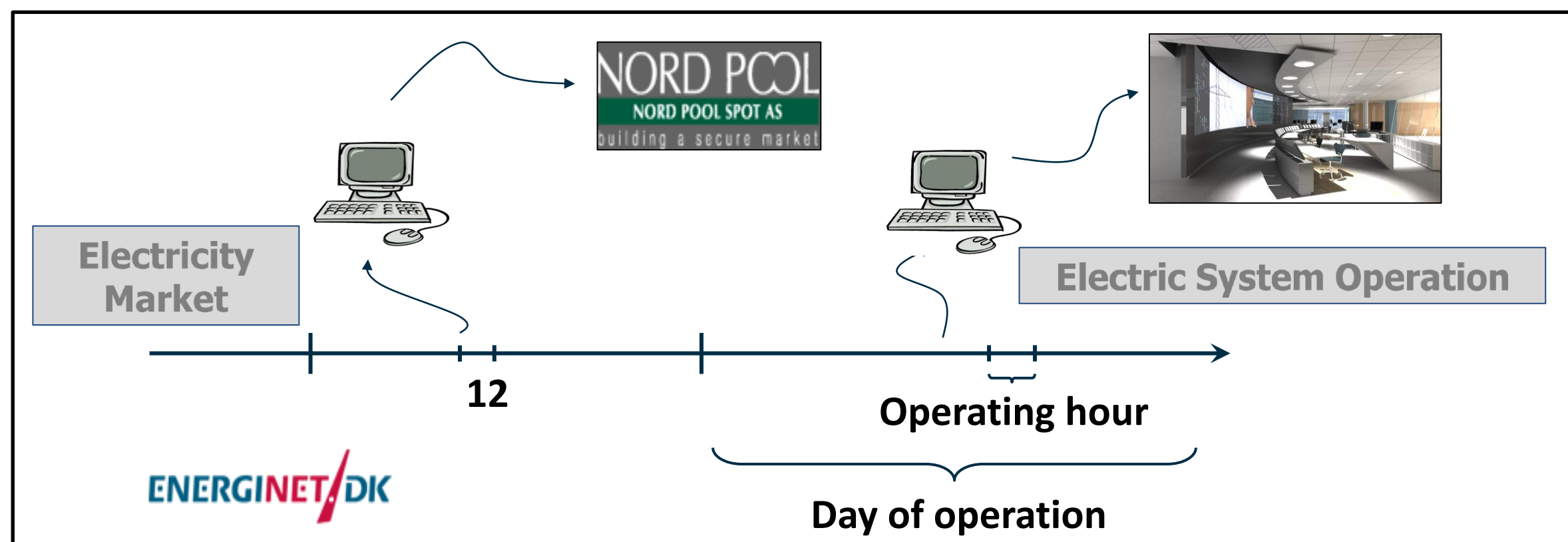
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PREDICTABILITY and VARIABILITY of the POWER OUTPUT of SELECTED WAVE ENERGY TECHNOLOGIES in the NORTH SEA

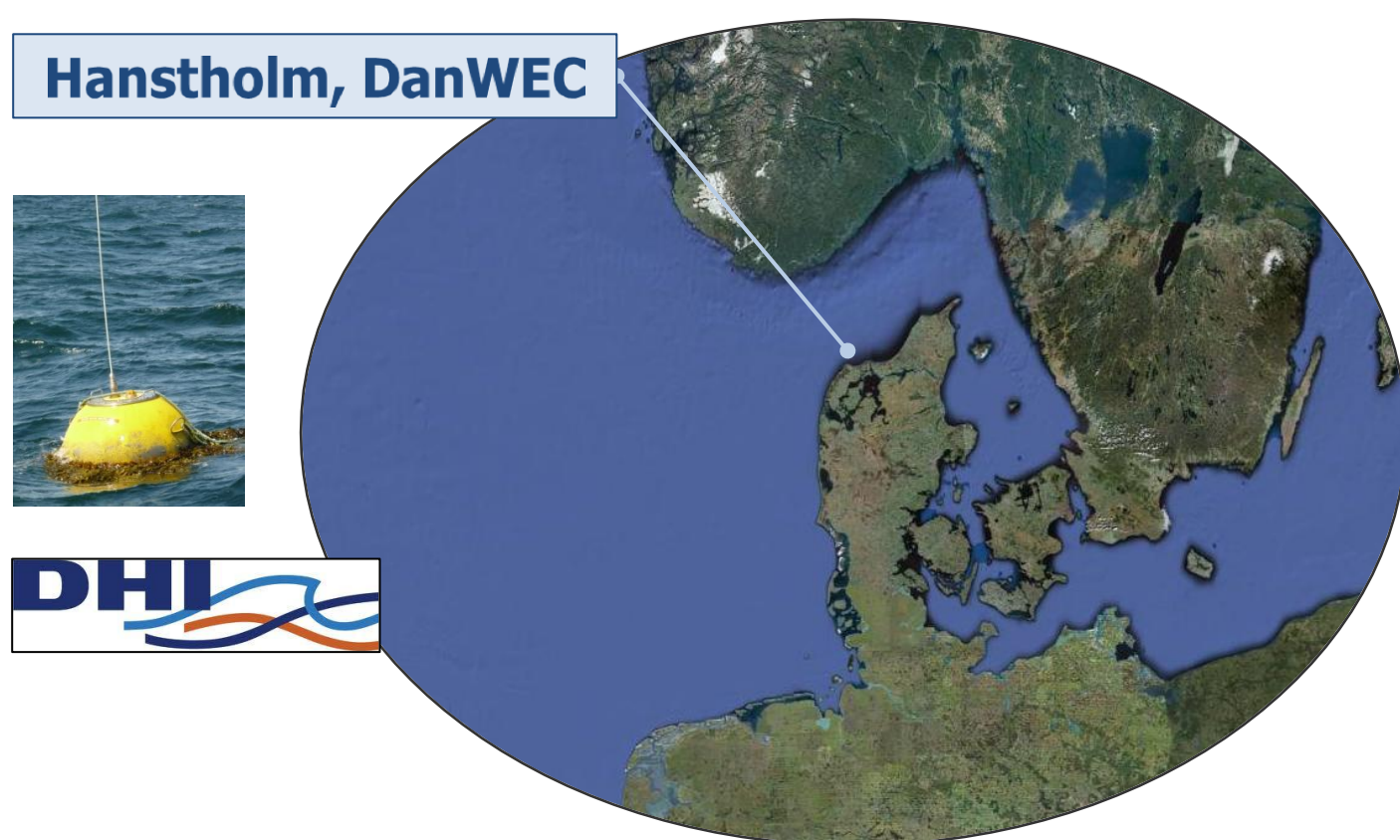
MSc. Julia Fernández Chozas (PhD Student)

- Integration of wave energy into the electricity market requires **day-ahead** forecast
- Danish day-ahead market: **12-36 hours forecast**
- Nord Pool** rules



- Integration of wave energy into the electric grid operation requires **short-term** forecast
- Danish grid operation: **0-1 hour forecast**

LOCATION



- Hanstholm site, Denmark**
- 17 m water depth and 1.3 km offshore**

STATISTICAL PARAMETERS

$$\begin{aligned} \text{Mean} &= \frac{1}{N} \sum_{i=1}^N \text{OBS}_i \\ \text{Bias} &= \frac{1}{N} \sum_{i=1}^N (\text{MOD} - \text{OBS})_i \\ \text{AME} &= \frac{1}{N} \sum_{i=1}^N (|\text{MOD} - \text{OBS}|)_i \\ \text{RMSE} &= \sqrt{\frac{1}{N} \sum_{i=1}^N (\text{MOD} - \text{OBS})_i^2} \\ \text{SI}_{\text{unbiased}} &= \frac{\sqrt{\frac{1}{N} \sum_{i=1}^N (\text{MOD} - \text{OBS} - \text{Bias})_i^2}}{\text{Mean}} \\ \text{CC} &= \frac{\sum_{i=1}^N (\text{MOD}_i - \overline{\text{MOD}})(\text{OBS}_i - \text{Mean})}{\sqrt{\sum_{i=1}^N (\text{MOD}_i - \overline{\text{MOD}})^2 \sum_{i=1}^N (\text{OBS}_i - \text{Mean})^2}} \end{aligned}$$

WAVE ENERGY CONVERTERS



Pelamis



Wavestar

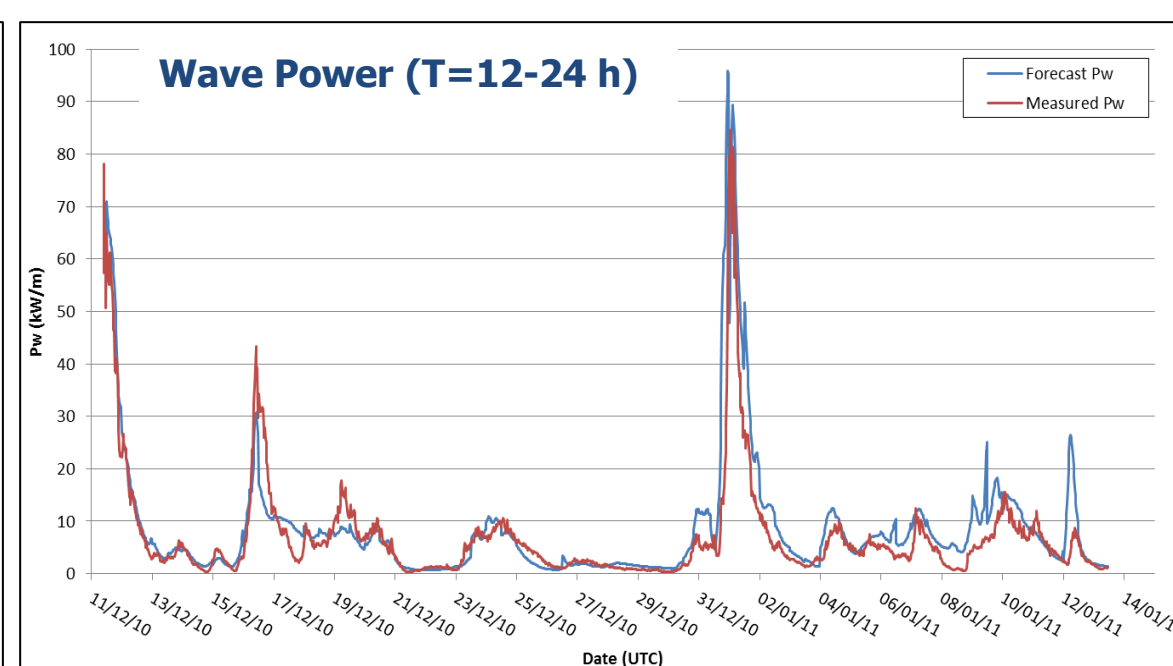
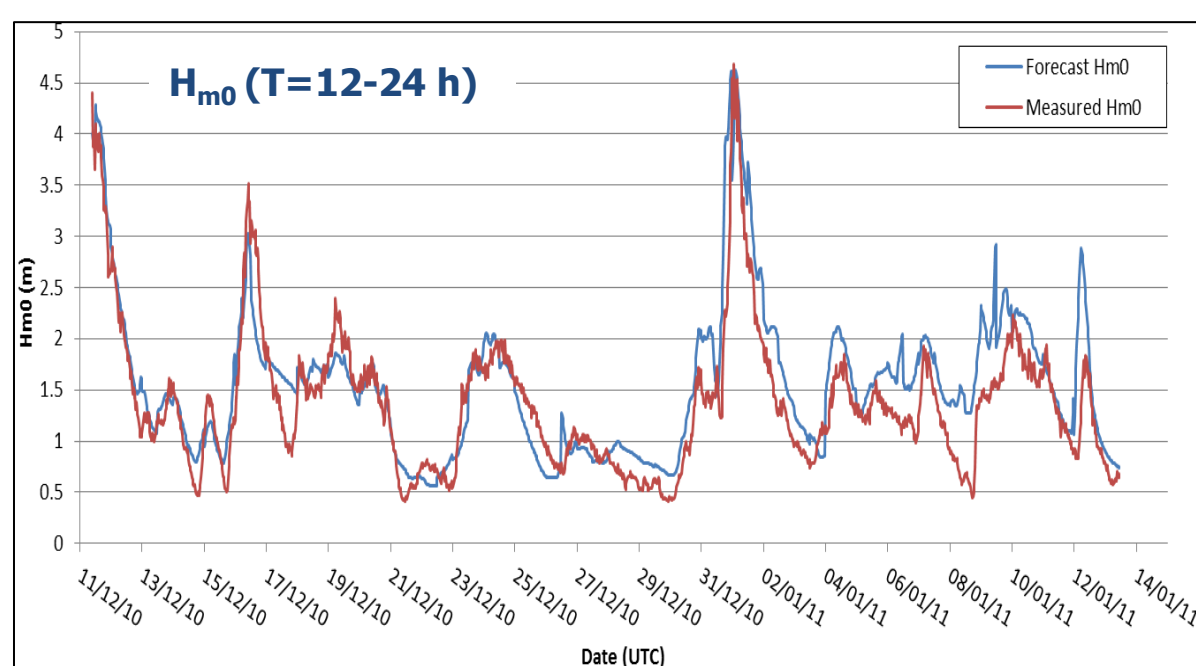


Wave Dragon

PREDICTABILITY

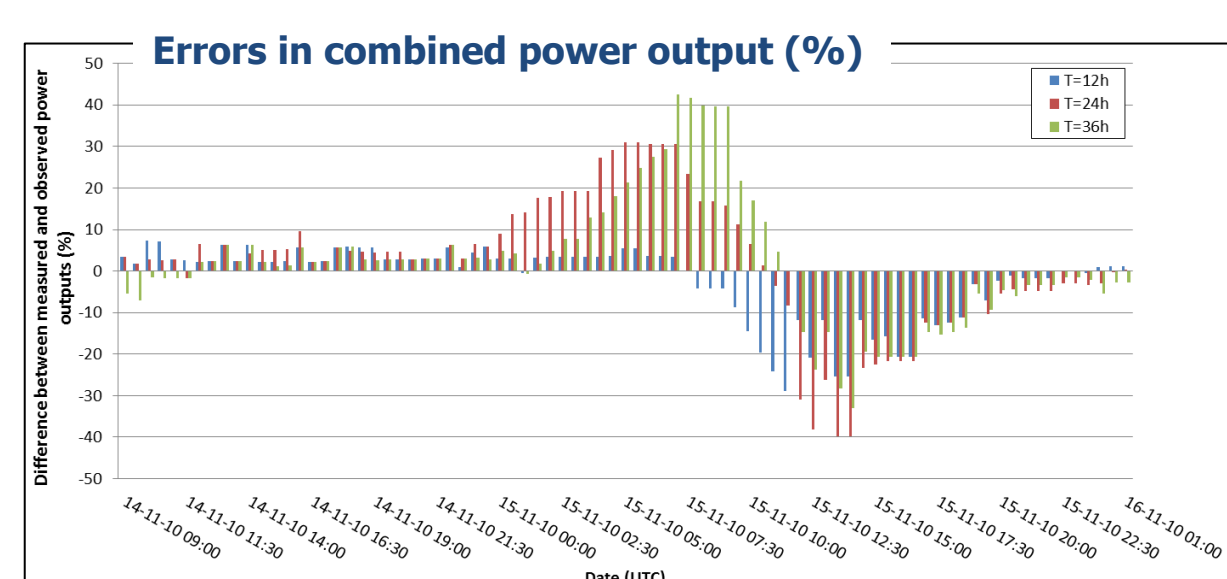
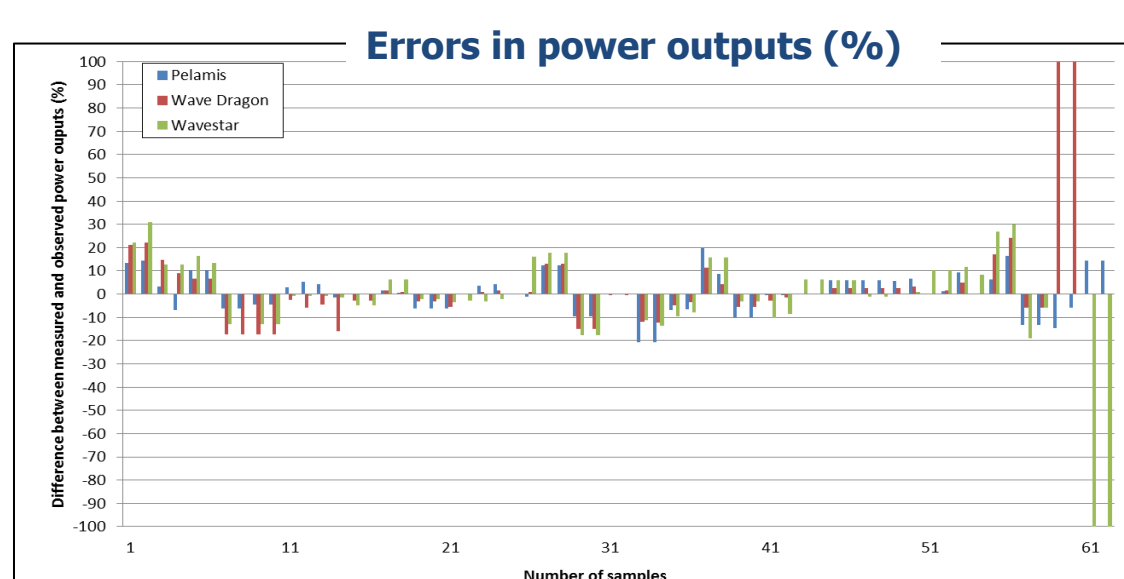
- Error statistics** of wave parameters forecast
- 12-36 hours forecast**
- Very acceptable** predictions

	Mean	Bias	AME	RMSE	SI _{unbiased}	CC	N
H _{m0} (m)	1.4	0.18	0.28	0.35	0.21	0.89	11901
T ₀₂ (s)	4.6	-0.17	0.42	0.56	0.11	0.74	11901
P _w (kW/m)	7.2	1.5	3	5.2	0.65	0.87	11901



- Error statistics** of the normalised theoretical power outputs of 3 WECs and a combination of the three of them
- 12-36 hours forecast**
- Best** forecast when **combined** power productions

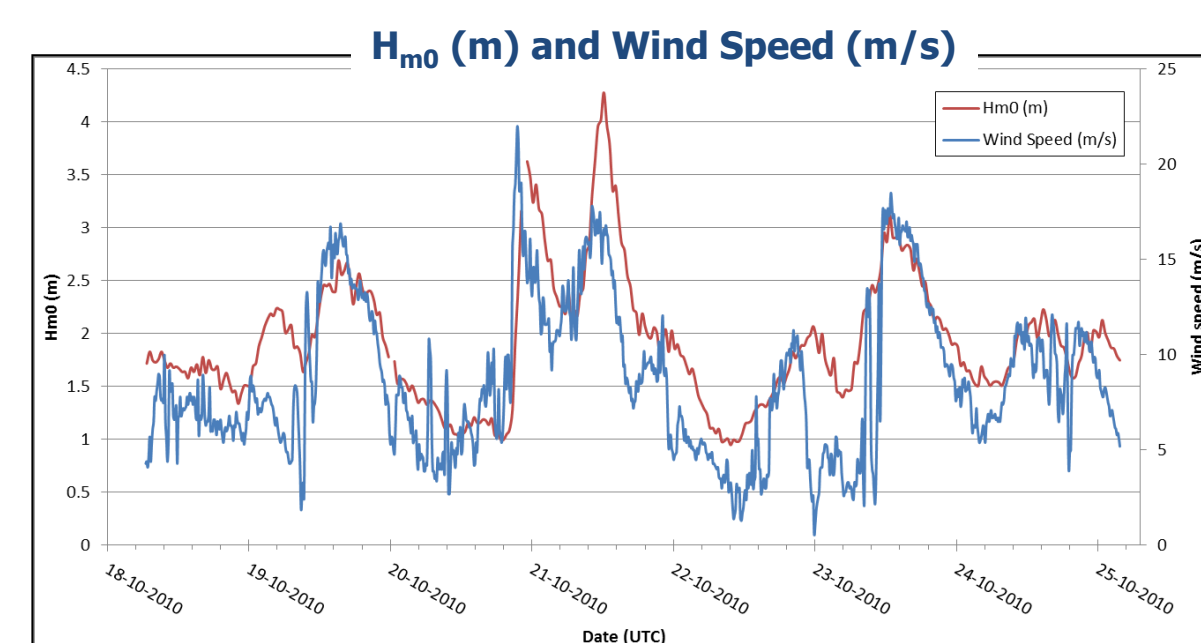
	Mean (-)	Bias (-)	AME (-)	RMSE (-)	SI _{unbiased}	N
Pelamis	0.29	0.07	0.11	0.15	0.44	11901
Wave Dragon	0.28	0.04	0.09	0.15	0.52	11901
Wavestar	0.39	0.04	0.15	0.24	0.62	11901
Combined	0.32	0.04	0.10	0.15	0.44	11901



VARIABILITY



- Pelamis**
- Wave Dragon**
- Wavestar**



- Delay** between wave and wind
- Variability **smoothens** out
- Better** accumulated forecast
- WECs continue **production** when wind **turbines cut-off**

Combined power output → Best forecast accuracy and High mean power production

Forecast errors on H_{m0} and T₀₂ do not accumulate - WECs respond different to predictions

Improved results expected when wind added

Looking forward to know more about it????!!!!!!
See you at EWTEC!!!!

9th ewtec 2011
European Wave and Tidal
Energy Conference Series